Cratering Studies in Polyvinylidene Fluoride (PVDF)

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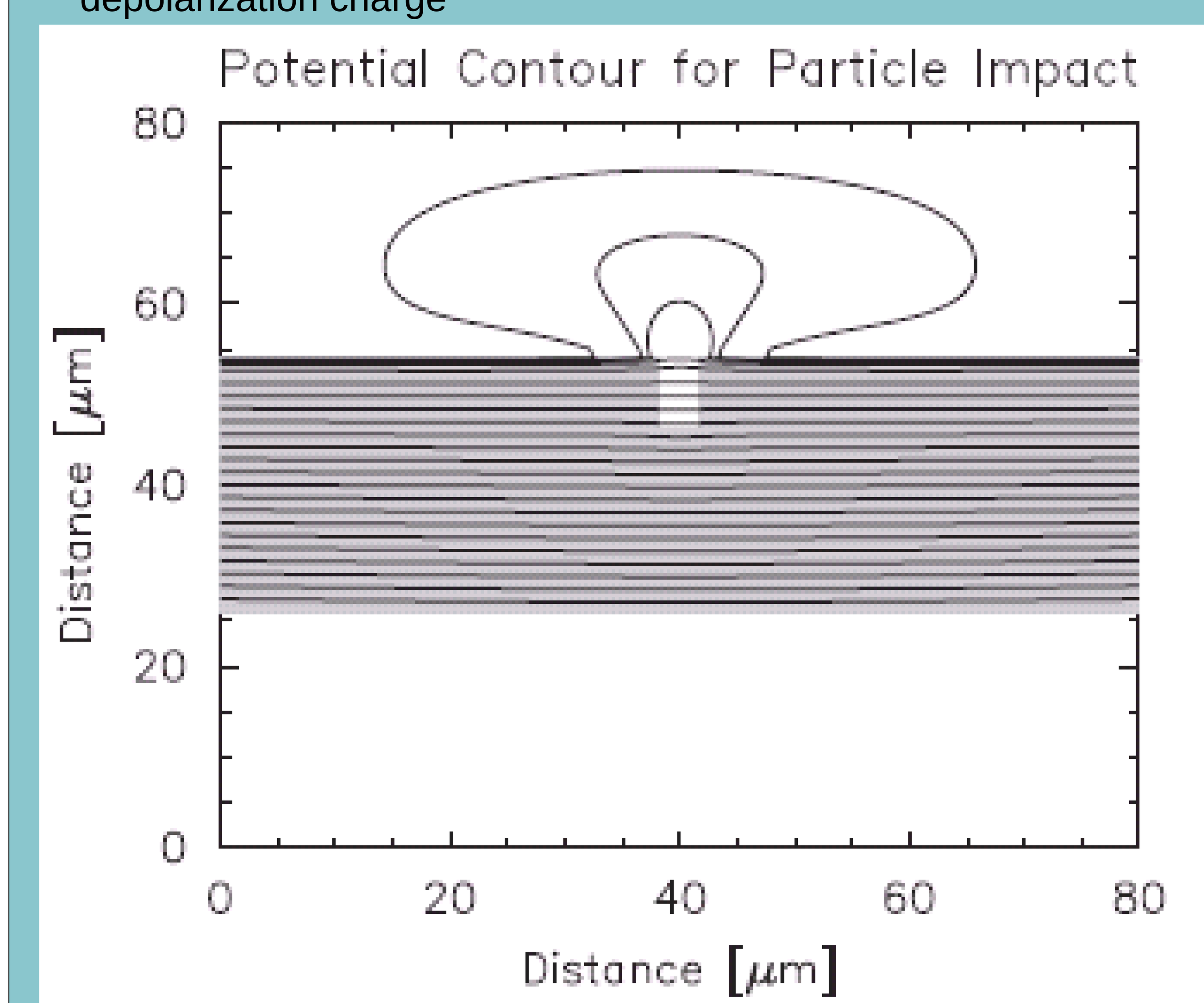
Introduction

Polyvinylidene Fluoride (PVDF) has been used as a dust detector on a number of missions including the Dust Counter and Mass Analyzer (DUCMA) instrument on Vega 1 and 2, the High Rate Detector (HRD) on the Cassini Mission, and the Student Dust Counter (SDC) on New Horizons. These dust detectors are made up of a permanently polarized layer of PVDF coated on both sides with a thin layer (≈ 1000 Å) of aluminum-nickel. The operation principle behind this type of detector is that a micrometeorite impact removes a portion of the metal surface layer exposing the permanently polarized PVDF underneath. This causes a local potential near the crater changing the surface charge of the metal layer. The dimensions of the crater determine the strength of the potential and thus the signal generated by the PVDF. The theory exhibits a bias as a function of experimental charge, which can be traced to the assumed crater diameter scaling law. Work is being undertaken to develop a new crater diameter scaling law using iron particles in 52 µm thick PVDF. Current studies were done at the Heidelberg Dust Accelerator Facility and analyzed at the Colorado Center for Lunar Dust and Atmospheric Studies (CCLDAS). Further studies using the CCLDAS dust accelerator are planned.

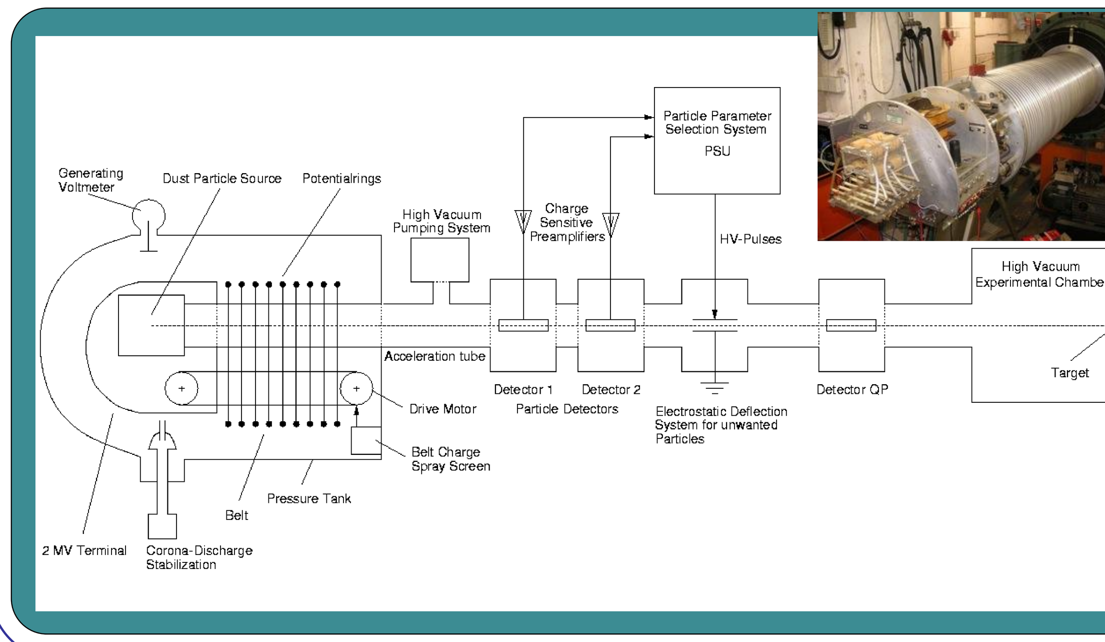
Theory

- PVDF is permanently polarized material.
- Both sides coated with ~100nm Aluminum-nickel
- Cratering removes metal layer and exposes polarized material underneath
- Net surface charge density is exposed creating fringing fields at bottom of crater
- Surface charge density near crater is changed creating depolarization charge
- Crater dimensions determine strength of fringing fields and depolarization charge



1. A. Poppe et al, *Nucl Instr Meth Phys Res* **622**, 583 (2010).
2. J. A. Simpson, A. J. Tuzzolino, *Nucl Instr Meth Phys Res* **236**, 187 (1985).

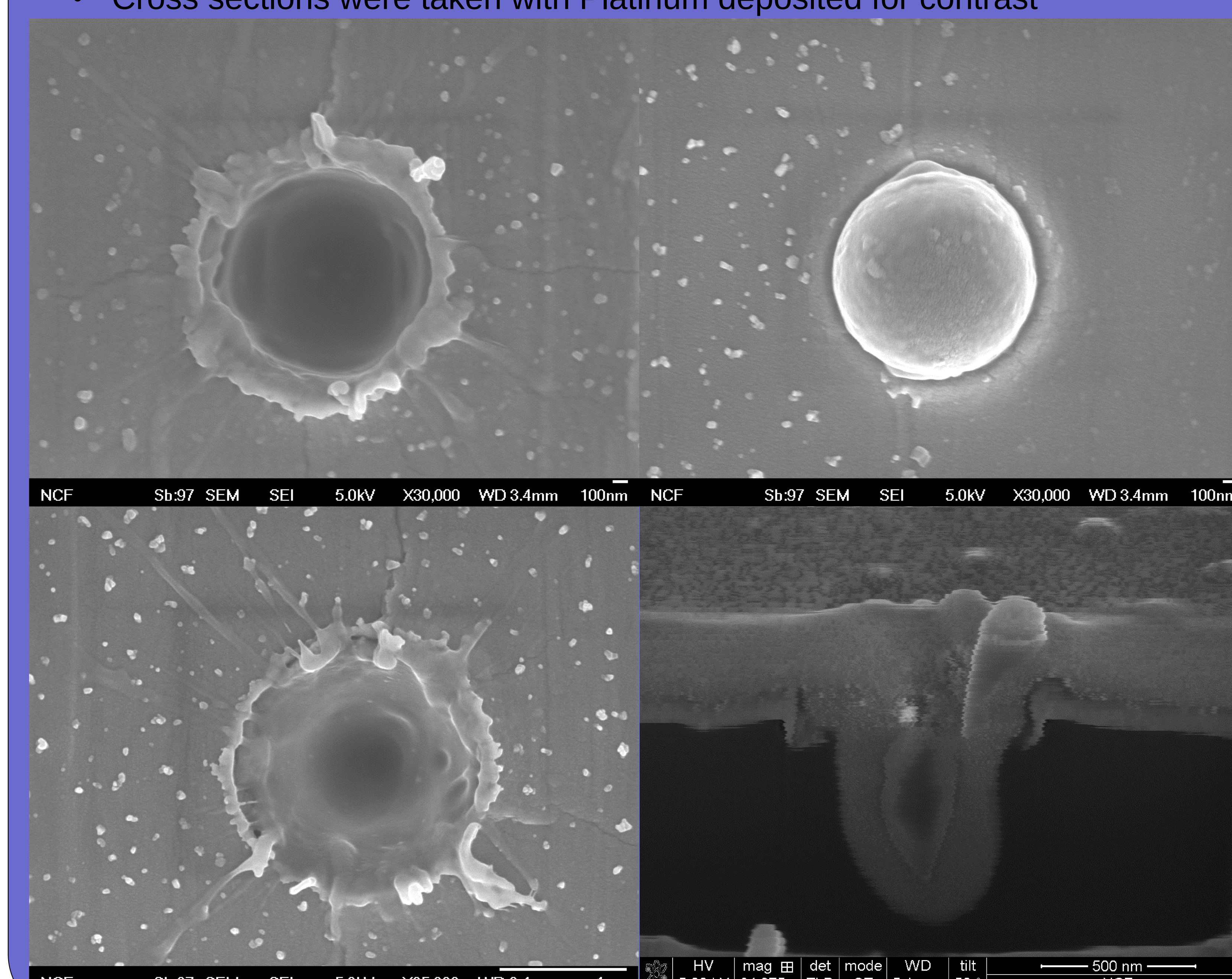
Experimental Setup



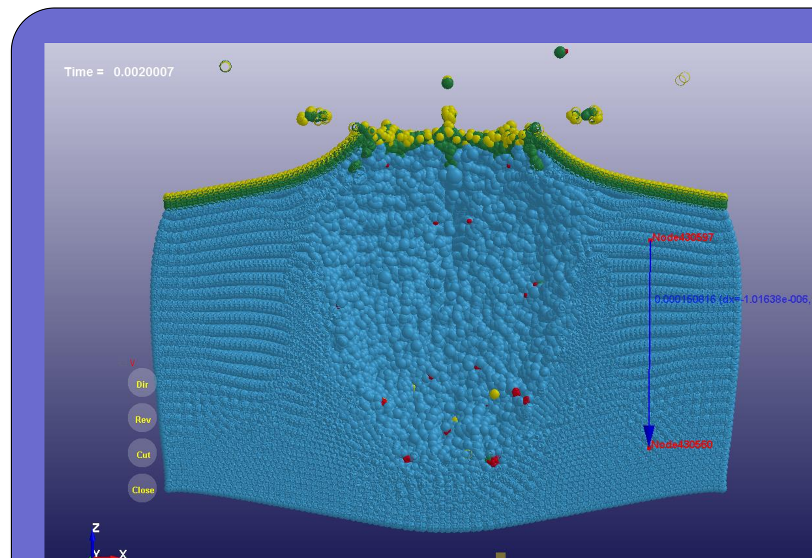
- Experiments carried out at Heidelberg Dust Accelerator
- 52 µm thick PVDF
- Iron particles at different size and velocity ranges
- 0.2-2.5 µm radius
- 0.5-10 km/s velocities
- Further experiments can be carried out at CCLDAS accelerator

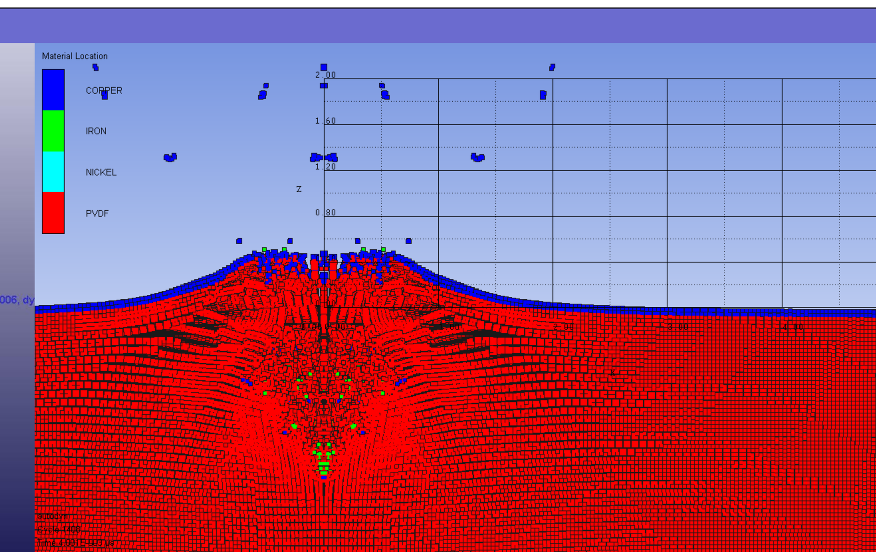
Crater Images

- Images taken at the Nanomaterials Characterization Facility
- Images were taken at multiple angles (all ones seen here are at 0º)
- Cross sections were taken with Platinum deposited for contrast



Crater Simulations

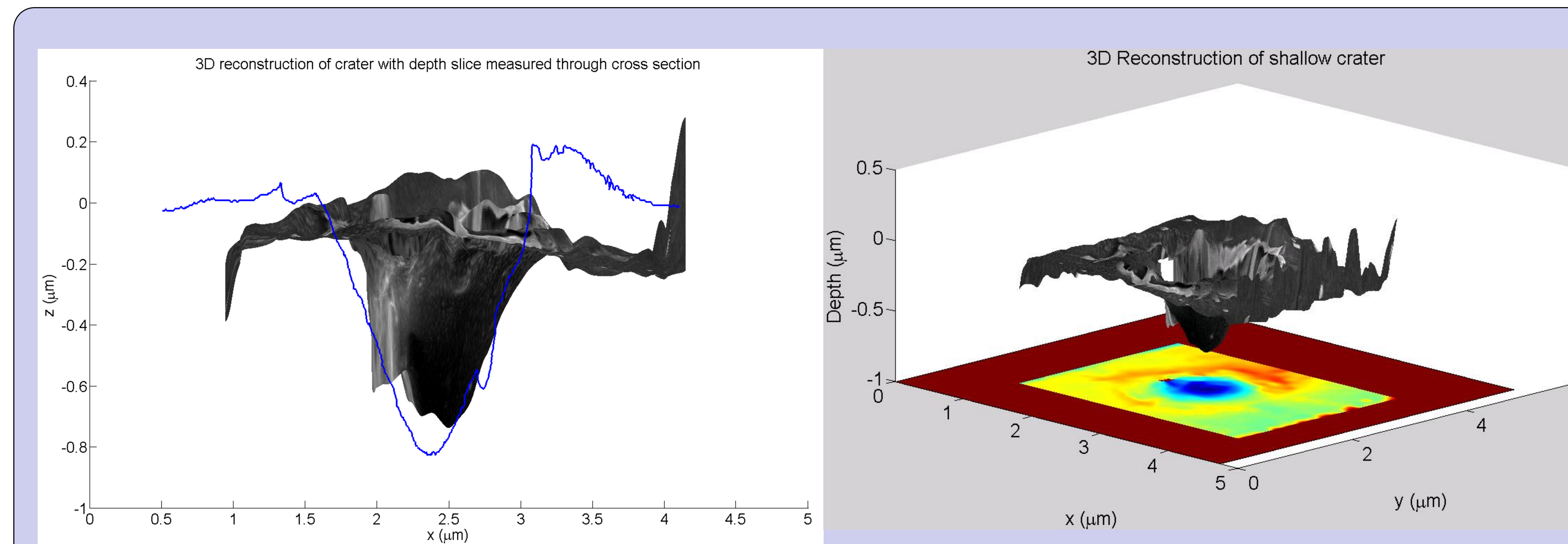




- LS Dyna
- Less SPH particles
- Faster, less accurate

- Autodyn
- More SPH particles
- Slower, more accurate

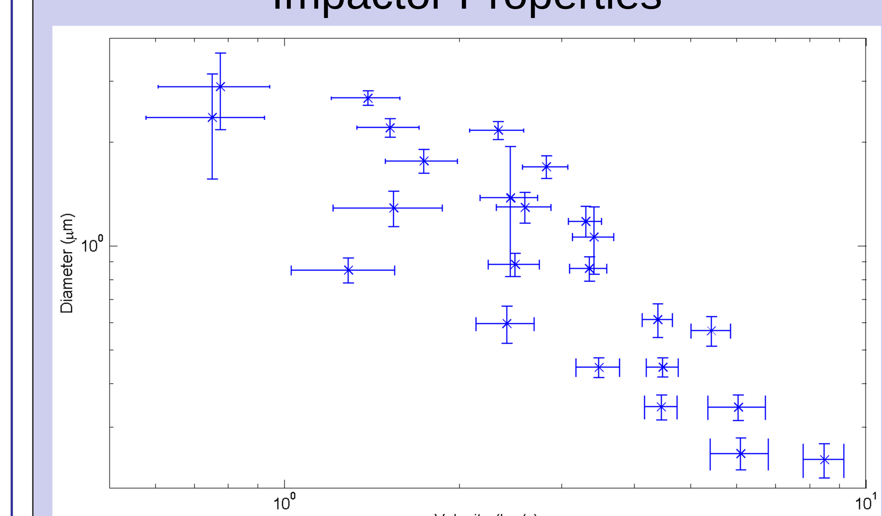
3D Reconstruction



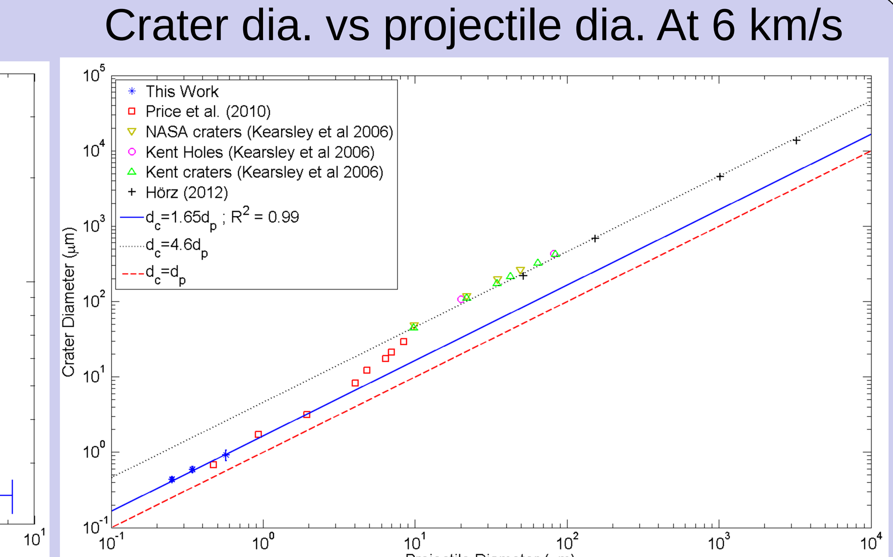
- Using two images at different angles 3D reconstruction of crater is created
- Reconstruction is compared to cross-section taken from focused ion beam
- Deep craters require better resolution in deepest regions

Results

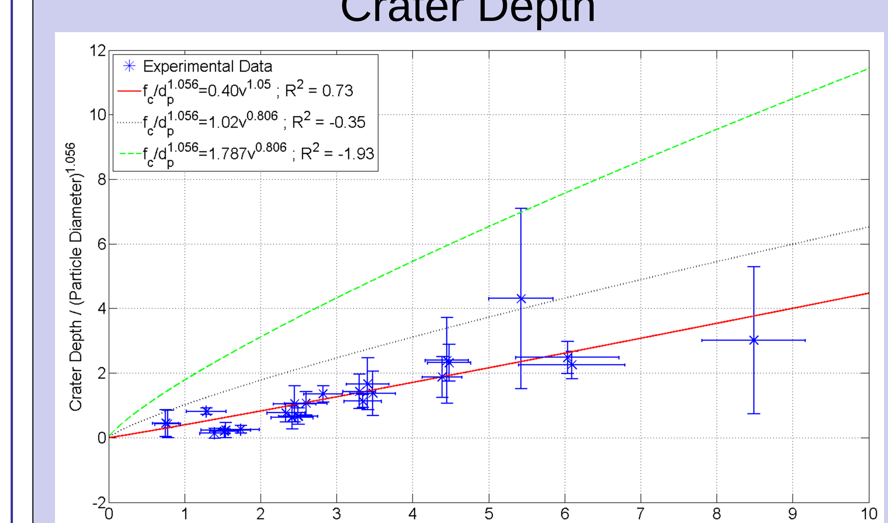
Impactor Properties



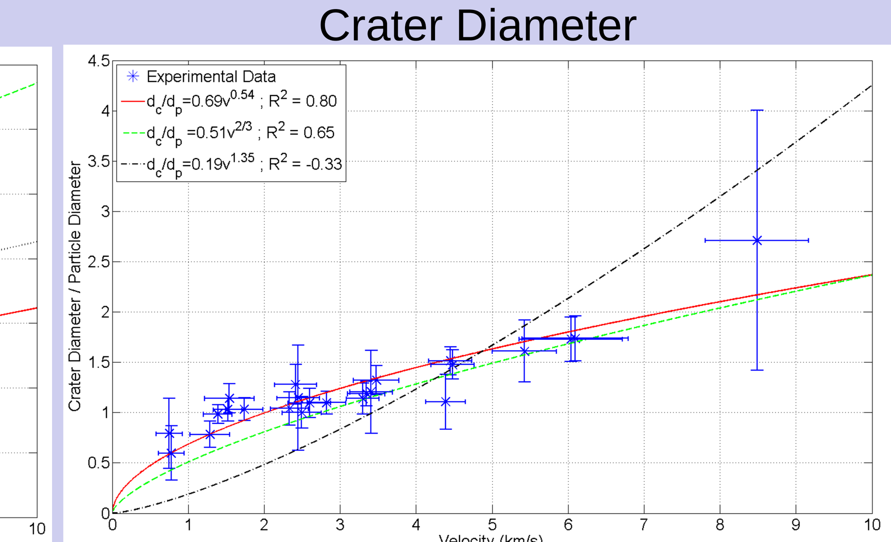
Crater dia. vs projectile dia. At 6 km/s



Crater Depth



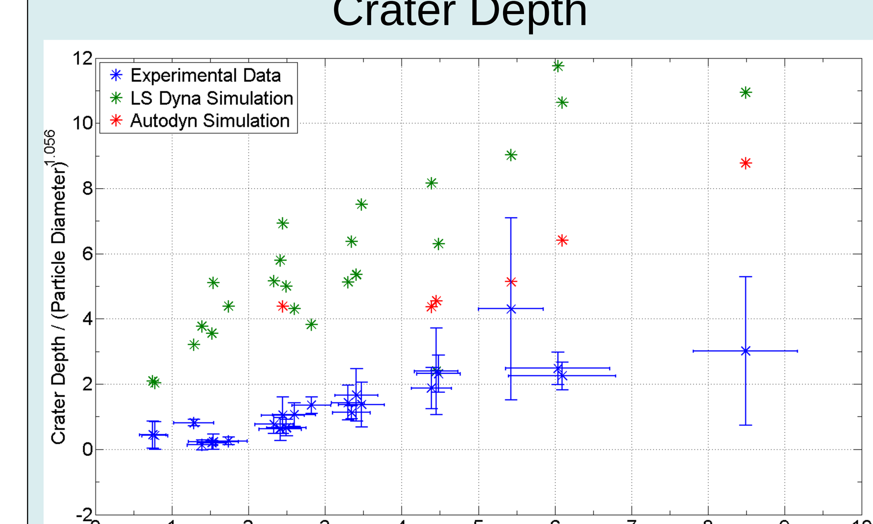
Crater Diameter



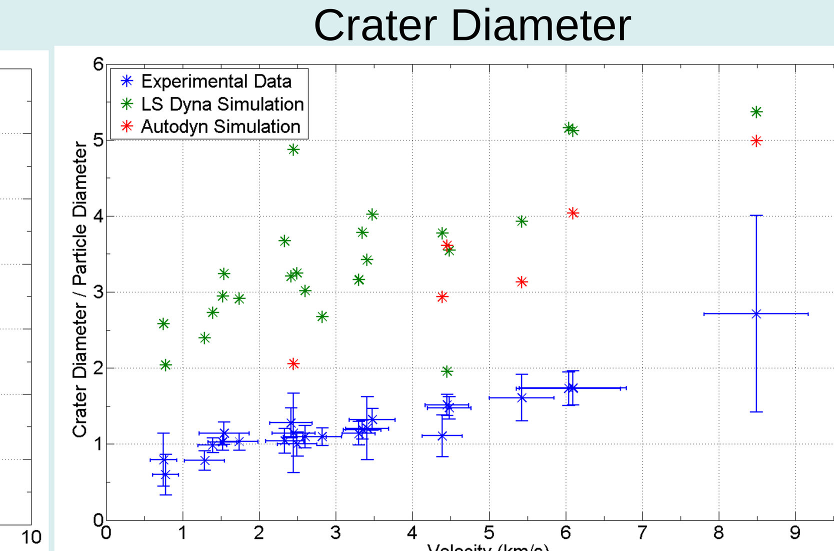
- Theoretical models based on different materials (Al on Al or Al on glass)
- Depth model does not easily translate across models
- Diameter model does work with different materials

Simulation Results

Crater Depth



Crater Diameter



- General trends are captured by SPH simulation but scaling factor is not
- Larger number of SPH particles gives higher accuracy in scaling factor
- More simulations with greater computing power must be run

- A. Routier-Kierzkowska, D. Kwiatkowska, *Functional Plant Biology* **35,** 1034 (2008).